Leveling up Learning: Finding the Flow Between Game Design and Education

An Honors Thesis (ICOM 495)

by

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Abstract

Games have become a prominent part of our culture, to the point of becoming a multibillion-dollar industry. Their upsurge in popularity has led to the discovery of new practical applications for games and game design, from physical therapy with “Wii Sports” (2006) to teaching science with “Foldit” (2008). I analyze why games have the ability to integrate into different applications seamlessly and what takeaways there are with encouraging the use of games as a tool for education.

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Process Analysis Statement

At the start of this project, I wasn't entirely sure what my end goal was. I simply wanted to see what links there were between education and game design. I had made educational games in the past for class projects but never formally studied why educational games work as well as they do. I originally planned my research by researching game design and educational practices individually and figuring out the overlap from there, but to my surprise, there's actually been a lot of research and experiments on specifically educational games and their potential impact. There was also a lot of researching psychological theories to help tie things together. As someone who started this paper with only an understanding of the game design aspect of this project, all the new topics proved to be quite the challenge to research and get an understanding of!

The paper took many forms over the course of its writing. It proved difficult finding a proper balance between writing about games and what makes them fun and rewarding, contemporary issues in education, and the proper way to link the two. This came to head towards the end of the semester after a massive restructuring and segmenting the paper into three parts. This allowed me to visualize each part on its own and see which pieces needed improvement. It also served as a great way to create a new flow for the paper and showcase every topic I've researched over the course of the semester. Ultimately, I'm proud of where the paper is in its current state and the multiple subjects that it jumps between flow together a lot better than I originally expected.

On top of the paper, I designed an educational game as means of taking what I learned to practice. The game, The Vault of Gebrala, is a "printable escape room" designed to help teach students exponents on an Algebra I level while being extremely easy for a teacher to print off and give to students. I've designed a printable escape room in the past as part of an Honors

Colloquium, so I already knew the best way to format it as well as certain puzzle ideas that translate really well for these types of games. This allowed me to design traditional escape room puzzles quickly while being able to focus on the educational material. I also decided to push the idea of a printable escape room further by adding a companion application to the project, which I created a paper prototype for.

When designing an educational game, a good theme is just as important as both the game and its educational material. In my case, since my theme was already heavily based in mathematics, I went for a slight hacker theme with each of the puzzles being due to data found from a character's cell phone. This worked surprisingly well for the game and allowed the puzzles to feel connected to each other, even if they are solved in completely different ways.

I chose Algebra I due to my background in mathematics, making it one of the easier subjects for me to design a game around. Originally, I wanted to design a wide range of puzzles that focused on multiple standards for Algebra I, but that proved to make the game lose its sense of theme and puzzle design suffered as a result. This made me scale back the scope of the game significantly to focus on just one state standard, exponents. This is for the better, as it allowed me to make sure both puzzles designed in the game to have a proper mix of escape room style elements, as well as teach nearly everything required from a student when it comes to learning about exponents in Algebra I.

Both puzzles at some point hit a point where simply printing out the game would start to become impossible. Most notably, one of my puzzles involves turning math solutions into a radio station, which then gives users part of code. This is when I came up with the idea for the companion app and began prototyping it. It would have been logistically impossible to create the app in the timespan of this project, so I opted to make a paper prototype instead. The images used to create the app, as well as the images for one of the puzzles, are all taken legally from free stock photo websites and edited together using digital photo editing tools. I then cut up notecards and put all the correct answers on them as a way of simulating players typing in their answers to the app.

Overall, I think my final project turned out well and effectively allows students to practice exponents in a unique and fun way. If given more time, I would have liked to actually produce the app and test it out as a completed product, as well as try again on teaching more than just one state standard with a much larger game. However, I think with the time provided I made something that demonstrates the potential educational games have and I hope people who play it have a good time and learn a bit about algebra as well!

Leveling up Learning: Finding the Flow Between Game Design and Education

Part 1: Popularity and Accessibility of Games

In 2008, a free, educational, game called “Foldit” was released for Windows, Mac, and Linux operating systems. This game was created by the University of Washington and addresses lessons in biochemistry. Foldit tasks players with folding selected biological proteins in a way to make them as physically compact as possible using the provided in-game tools. Players are then assigned a score based off of how well the protein was folded (“Foldit Taps Power of Videogames to Solve Complex Protein-Folding Puzzles.”, 2013). Despite the game’s heavy basis in biochemistry, the player base comprised of mostly people with no scientific background in biochemistry, at most only having one college class on the subject (National Science Foundation, 2011). In 2011, scientists, unable to piece together a protein-cutting enzyme from a virus similar to AIDs, turned this challenge into another Foldit puzzle for players to solve. In just a couple of days, players were able to use Foldit to create a working enzyme of the AIDs-like virus for scientists, a task that researchers had been struggling to do for over ten years (“Foldit Taps Power of Videogames to Solve Complex Protein-Folding Puzzles.”, 2013). In such a short amount of time, players were able to help solve a puzzle that scientists couldn’t and potentially change the course of medical history for the better all by simply accepting a new challenge in a game that they found fun.

It is no big secret that games are popular. According to the Entertainment Software Association, over 150 million Americans play video games, 28% of which are below the age of 18. In 2016, video games alone made over $30 billion in revenue (“Industry Facts.”, n.d.). Mobile gaming has notably earned a strong lead thanks to games like Pokémon Go, a geolocative game where players explore the world around them in search of virtual creatures, making over $2 billion globally in a little over a year after its release in 2016 (Tassi, 2018). A major factor in Pokémon Go’s success is that it includes a strong social interaction component, with events, such as Pokémon Community Day, allowing players to meet up and work together to achieve common in-game goals such as trying to fight and capture a rare Pokémon in what are known in the game as “raid battles” (Forsythe, 2018). Implementation of games has also proven to have potential in healthcare fields with games such as Wii Sports, which uses motion sensors inside the controller to detect player movement and simulate sports such as golf, tennis, and bowling. This proved to be helpful as a form of physical therapy, with reports of increased balance and faster recovery speeds due to patients wanting to play the game even in their free time, something that could not be achieved with traditional physical therapy methods (Mickey, 2012).

With so many applications for games as a medium beyond just entertainment, it seems only natural that uses in education would be found for games as well. Educational games have been around for a while with one of the most famous being The Oregon Trail, a computer game designed to teach children about the historic trail of the same name (Grisham, 2015). Since then, educational gaming has taken popularity in the classroom with new educational games being continuously designed, such as Minecraft: Education Edition, an educational game focused around building in a three-dimensional space with virtual blocks. Minecraft has numerous educational applications in math, science, programming, and history (“What is Minecraft”, n.d.).

From entertainment to education, what makes gaming so popular to implement in various fields? There is the inherent interactivity that games have that other forms of entertainment and storytelling do not have, as well as the immediate feedback the player gets when interacting with a game. There is also the fact that, thanks to smartphones, games are easier to access than ever before, but there is another thing that games have mastered which helps them integrate subjects such as education and physical therapy easily: Flow Theory.

In the 1970s, psychologist Mihaly Csikszentmihalyi coined the concept of “flow”, a feeling in between anxiety and boredom where someone feels an extreme amount of focus on accomplishing one specific goal, sometimes creating a lack of awareness about the rest of their surroundings and creating a feeling of time moving faster than it actually is (Nakamura & Csikszentmihalyi, 2014).

In his piece, *The Concept of Flow,* Csikszentmihalyi describes two states of being that put someone in a state of flow, declaring that “perceived challenges, or opportunities for action, that stretch (neither overmatching nor underutilizing) existing skills; a sense that one is engaging challenges at an level appropriate to one’s capacities” (Nakamura & Csikszentmihalyi, 2014, p. 90). The characteristics of being in a state of flow include a heightened sense of focus and control, a distortion of feeling in time, and a feeling that the act of completing the task was intrinsically rewarding by itself. Once someone is in a state of flow however, they must also be able to maintain it. As Csikszentmihalyi states, “If challenges begin to exceed skills, one first becomes vigilant and then anxious; if skills begin to exceed challenges, one first relaxes and then becomes bored” (Nakamura & Csikszentmihalyi, 2014, p. 90). This middle ground between boredom and anxiety (figure 1) is what can make completing tasks engaging, rewarding, and encourage people in a state of flow to learn and improvement at the given task. This makes Flow Theory a valuable tool in designing goals that people feel motivated to achieve in any field, including game design.

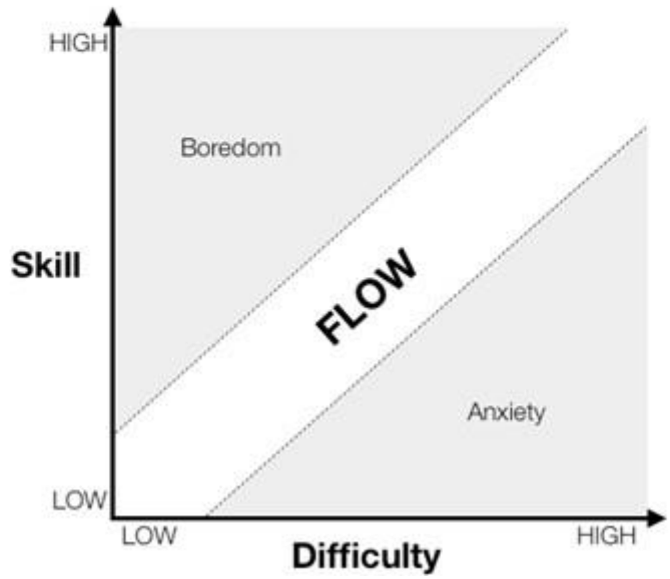

Figure 1. A diagram of how flow interacts with user difficulty. Adapted from Baron, S. (2012, March 22). Cognitive Flow: The Psychology of Great Game Design. Retrieved from http://www.gamasutra.com/view/feature/166972/cognitive_flow_the_psychology_of_.php

In game design, flow theory is used when trying to find the “right” difficulty for a game. However, as every player is different, there is no singular level of difficulty that will work for every single person. There are two popular solutions that game developers implement to try and allow for a wide range of players to achieve a state of flow. The first, and most frequent, option is to have multiple difficulty options that players can choose between at the start of the game to match their preferred difficulty. “Easy,” “Normal,” or “Hard” options are the standard that players are used to seeing in most games (Baron, 2012). While this is popular, it is a very rigid structure and does not necessarily cover every single player. The other option is to create a dynamic difficulty that adjusts the game automatically based off how the player is doing (Baron, 2012). This is most famously used in Valve’s “Left 4 Dead”, a cooperative action game set in a zombie apocalypse, which had the game adapt to how well the players were doing by either giving more in-game supplies if they were struggling or by creating tougher enemies if they were performing well. Regardless of which way is chosen, both achieve the same goal of catering to a wide variety of people at various skill levels, allowing for more people to achieve a state of flow with their game (Booth, n.d.).

To be able to keep that proper level of anxiety, there needs to be a threat of failure. If it becomes clear to the player that there is no way for them to lose the game, boredom sets in. However, if the threat of failure becomes too prominent, the player will become too anxious and lose their state of flow. This has led to game developers learning to master balancing failure so it feels like a constant challenge that the player has to work to overcome, but not an overwhelming force that ruins the experience. How game designers do this will vary from game to game, but a common way to accomplish this is to not directly punish the player for failure. Failure only serves as a roadblock for player until they are able to overcome it and progress further into the game with new, more difficult, challenges to face. Once the player proves that they can overcome that failure, they move on the same as anyone that may have not struggled in that specific moment. This freedom of being able to fail and try again for as long as the player likes is vital for helping keep a state of flow and motivate players to keep playing the game and improve how they play. This state of flow is what makes games powerful as a medium. When physical therapy patients play Wii Sports, they are achieving a state of flow which helps motivate them to play more and improve their health. Similarly, Foldit players were able to achieve a state of flow with their game, allowing them to solve a problem that not even top researchers were able to figure out and help potentially cure a strain of AIDs. It is this inherent value that games have when achieving a state of flow that can be taken away into other mediums and applied elsewhere.

Part 2: Contemporary Issues in Education

Numerous studies point to new ways to help students with their education and keep their attention in class. One of these studies was performed by Judy McShannon and Patricia Hynes from New Mexico State University in 2005. Their studies concluded that "...engaging students in discussions, group work, and active problem-solving can be more effective than lectures for developing students' critical thinking and problem-solving skills" (McShannon & Hynes, 2005, p. 88). The study focuses on the ways in which traditional lectures appear to not be helping students interact with the course material, and instead suggests more dynamic approaches to education. One of those approaches is giving students an in-class question to demonstrate their understanding of the concept, which "...tell faculty whether students understand the material presented, reveal whether students grasp all or part of the concept, and give students an opportunity to speak in the language of the discipline" (McShannon & Hynes, 2005, p. 88). These questions, while being used as means of assessing a student's given understanding of the subject and to allow for better student participating, also help to see if students are able to analyze the problem and apply what they know about the course material to solve the problem.

There are many ways to assess a student's abilities to understand and apply what they know on a given subject. Bloom's Taxonomy, created by Benjamin Bloom in 1965, is one such method of classroom assessment. Bloom's Taxonomy (figure 2) is a learning hierarchy designed as a means to organize a person's mastery of any given subject. It is divided into six categories of increasingly complex critical thinking and cognitive processing. These six categories are "remember", "understand", "apply", "analyze", "evaluate", and "create" (Armstrong, 2018). The process of challenging students in course materials with assignments geared toward higher levels of critical thinking and cognitive processing can be associated with the "apply," "analyze," and "evaluate" tiers of Bloom's Taxonomy. A student's ability to master various learning objectives and standards associated with a course can be assessed by challenging students in ways that encourage critical thinking, as the McShannon and Hynes study evaluates. However, this can be difficult to achieve. Even if an instructor creates a lesson plan that challenges students and hits the higher levels of Bloom’s Taxonomy in their instruction, that does not mean that an individual student will be ready for those specific tiers. This makes lesson planning for teachers difficult, as a lesson plan that tries to challenge students and hit the higher tiers of Bloom’s Taxonomy will cause issues for students that are struggling with trying to remember or understand the basic materials, but a lesson plan that is focused on just the lower tiers runs this risk of being boring for students who can already grasp that information easily. This creates a challenge for educators to create lessons that scale to fit individual student’s needs depending on where they are in relationship to both Bloom’s Taxonomy and the content of the class. If a teacher does not create lessons to suit individual student needs, they run the risk of the lesson either being too easy or too difficult.

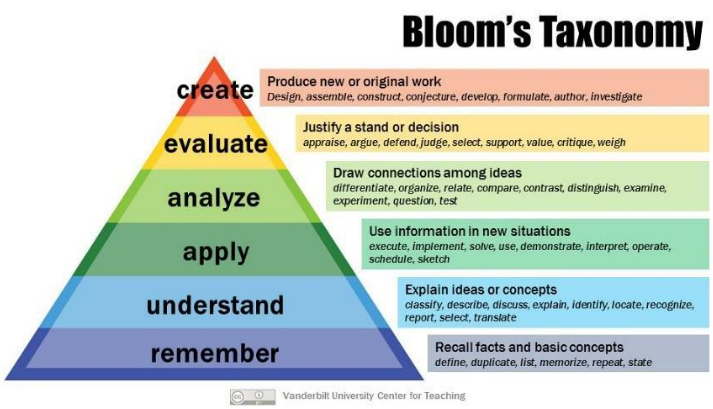

Figure 2. Bloom’s Taxonomy. Adapted from Armstrong, P. (2018, August 13). Bloom's Taxonomy. Retrieved from https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/

This is the same issue that game designers face when balancing difficulty for gaming in respect to flow theory. When a course is designed to be too difficult, or that the threat of failure starts to feel overwhelming, students gain a sense of anxiety and lose their state of flow. If a course is too easy, students will get bored and lose their state of flow. Both ways result in a loss of a student's attention in the course and any intrinsic motivations they have to complete the work will be diminished. To make sure that as many students achieve a state of flow in education, an educator needs to properly determine where student skills lie in terms of their ability to achieve different states of cognitive processing, as described by Bloom's Taxonomy.

For a given subject, designing course materials to scale with a range of student skills, allows students to achieve a personal state of flow. Subsequently, maintaining that state of flow by steadily adjusting the difficulty of the course as students start to move to higher levels of processing within Bloom's Taxonomy, produces not only effective scholarship but also pleasurable classroom experiences. This can be a difficult task for educators, as it is hard to predict how much each individual student knows about a given topic, or how quickly they will be able to learn about it while also trying to teach an entire class. As such, creating dynamic, unified lesson plans that allows students to optimally achieve a state of success as assessed by Bloom's Taxonomy while also achieving a state of flow can be nearly impossible without employment of drastically new and different styles of teaching in the classroom.

Part 3: Games in Education

Games or game-like structures are already widely used in education today. With constant use of games with inherent educational value, like Minecraft and the Oregon Trail, it has become common to study why games can have such educational value and figure out how to design games with education as a primary focus. The study of games in education is commonly known as the study of “Serious Games”. Coined by Ben Sawyer in 2002, Serious Games are games that are designed with the intent of being educational from the start, as well as still maintaining what makes traditional games fun and entertaining (Sawyer & Rejeski, 2002; Gunter, Kenny, & Vick, 2006). Serious Games can take many forms in the classroom, such as allowing students to play an educational game like Sid Meier’s Civilization, a game about raising a civilization from the stone age into the modern age while dealing with issues such as economics, famine, or war, and has educational value in topics such as the effects different political systems can have on a nation and the concepts of international diplomacy (Gunter, Kenny, & Vick, 2006). Other times this is achieved by turning the classroom into a game in its own right. This is a process typically referred to as “gamification” or “gamifying the classroom”. Gamification can be best defined as “the application of game mechanics to non-game activities” (Sheldon, 2016, p. 75). An example of this comes from a racing game designed by B.D. Coller to teach numerical methods. The game resulted in twice the time spent playing the game by students when compared to completing traditional homework, "with greater depth of understanding of the relations between concepts, and an overwhelming demand for the follow-up course” (Mayo, 2009, p. 80).

From studies of Serious Games, it is clear that Bloom’s Taxonomy produces a strong overlap between education and game design, such as another study from the University of Central Florida reaffirms. The study discusses three different learning structures and how they relate with game design. Bloom’s Taxonomy was one of them, with the other two being ARCS

Motivational Model and Gagne’s Events of Instruction (Gunter, Kenny, & Vick, 2006). Because all three structures are learning hierarchies that increase in cognitive complexity as one progresses through them, only Bloom’s Taxonomy will be discussed in relation to game design, but similar things could be said for the other two hierarchies.

What this study notes is that game design inherently allows someone to climb through Bloom’s Taxonomy in the exact same way as education does. When creating a game, its designer needs to make sure that the player understands the basics of how to play before the game moves on to more complex challenges that the player has to complete, effectively holding a player in lower levels of Bloom’s Taxonomy until they prove they understand how to play the game and progress further in it. The game also has to make sure to balance its difficulty so that players do not find the game too easy, or else they lose their sense of flow. Similarly, educators have the previously stated challenge of trying to bring students from lower levels of Bloom’s Taxonomy into the upper levels, but only when they show enough mastery of the subject to advance, while also balancing students who are already in the higher tiers (Gunter, Kenny, & Vick, 2006). These are inherently the same problem, allowing for Bloom’s Taxonomy to become a point of merger between game designers and educators. If an educator is designing a game with the steps of this hierarchy in mind, they have a road map for both how to pace a game, its difficulty, and how to start incorporating educational value into games.

One example of this comes from a case-study involving grade-school level students in Taiwan learning about energy use and consumption through a card game. Students took a pretest before playing the game and a posttest afterwards, both designed to assess their current scientific knowledge. The game is designed to follow Bloom’s Taxonomy to align the game with the educational material by increasing the difficulty of the game as it starts to require a better understanding of the course material. This had a positive reception from students with posttest scores averaging 10% higher over pretest scores. This is the positive impact that using one game for one subject can have on a classroom (Liu & Chen, 2013).

Education can use flow to engage learners and create a state of constantly challenging them while giving them a feeling of being in control similar to a flow state in video games. Learners achieve flow at different difficulties similarly to how games have to use multiple difficulty levels as a means to have as many players achieve a state of flow as possible. This already exists in most schools to a degree. If a student is struggling at a specific subject, they can take an easier, remedial level, course or they can take a more advanced course with an increased difficulty. This is flawed however, as it is a rigid structure that doesn't allow for much room for growth to an individual student. If they are struggling with one course, they fail and take an easier course, potentially delaying the rest of their graduation schedule. If a course is too easy, a student can't transfer into a harder one, they are stuck in the easier class. Without courses that scale to the student, it is near impossible for them to achieve a state of flow and actually learn and enhance their mastery of the given material.

This overlap between flow as a state of learning and Bloom's Taxonomy as an assessment of learning outcomes has been tested before in a study by the University of Amsterdam with a history game on the medieval history of Amsterdam. Students played as characters of different social statuses, such as merchants and beggars, in groups of 4 in order to obtain 366 points (the amount of days it takes to earn citizenship in medieval Amsterdam) through various objectives and tasks. This study showed that students who achieved a consistent state of flow during the game, usually by competing against other teams of students, also showcased a higher understanding of the educational material of the game via a posttest taken afterwards (Admiraal, Huizenga, Akkerman, & Ten Dam, 2011).

While the study showcases how flow can be used to link games and education, it also shows a potential drawback. In the study, it was recorded that students in higher-level classes typically benefited from the game while lower-level classes benefited more from a traditional lecture (Admiraal, Huizenga, Akkerman, & Ten Dam, 2011). This could be argued to be because students who had a higher understanding of the material were in the "understand" and "apply" levels of Bloom's Taxonomy, while students in the lower-level classes were still in the "remember" level. While an educator can design an educational game with flow in mind and have students to benefit from it, if the game is designed to be too difficult or too easy, the state of flow is lost and the educational value along with it. This again shows that scalability is important when designing both a traditional and gamified curriculums.

When taken to the extreme, games in education can turn into a full blown "gamified" classroom. As stated earlier, this is the process of turning the entire classroom into one giant game. This style of education is naturally harder than simply creating one game for one subject, but contains valuable takeaways that can be applied to education as a whole. While at first it seems like these classes are completely reinventing the classroom from scratch, that cannot be farther from the truth. Most of these classes are not doing a major restructuring like one would think, they are more like simple rebrandings. Grades are typically referred to as "Experience Points" (EXP), assignments and projects are "quests", and tests are "boss fights" or "raid battles". This seemingly does not change the core structure of the class so much as put a fresh coat of paint onto things (Sheldon, 2016).

This does not seem like much at first, however, as Lee Sheldon, experienced game designer and educator, states in his classroom design textbook, *The Multiplayer Classroom*, there is a reason why the EXP system is important. In a traditional classroom, it feels as if the student is losing points for making mistakes instead of gaining points for the questions that the students answered correctly. The EXP system instead makes students feel like they are constantly gaining points and that any mistake they make simply means they are going to gain less points (Sheldon, 2016). The student does not feel like they are being punished for their mistakes, but rather rewarded for their efforts, similar to how traditional game designers are learning to avoid punishment for failure in their games. This recontextualization should be noted by educators, even if they do not plan to gamify their entire classroom.

Another aspect that seems common amongst all “multiplayer classrooms” is the open-ended nature of the classes. In case studies for both Marked Tree High School and the University of Arizona South, students had the choice of what quests they could pick from and were rewarded for picking harder quests with more EXP (Sheldon, 2016). This has two benefits; it rewards students for attempting harder assignments, giving then a greater understanding of the course subject and, more importantly, it also allows students to fail. As stated previously, games typically do not directly punish a player for failure. If a player fails to win a major fight, they simply start the fight over. If a player loses at a card game with friends, they can just start another round and try again, eventually allowing them to improve at the game. In most classrooms, if a student fails a test, they do not get another attempt at the test, creating a permanent negative impact on their grade. This could potentially cause a student to either retake the class or be held back another year. As it stands, the current educational system does not give students the freedom to fail without repercussions.

As game designers are learning to allow players to fail and learn from their mistakes, so too do educators need to learn ways that allow for students to fail. Utilizing the quest-based classroom as seen in the case studies allows students to fail an assignment without permanent repercussions. If they fail a quest, they can choose to either try it again or work on a different quest entirely (Sheldon, 2016). This type of system is not always possible; school policies can dictate what an educator needs to focus on and statewide standardized testing would force an educator out of any gamified classroom back into a traditional one. There is also the counterargument that if one were to fail at doing their job in the real world, they would be fired, not educated. While this is true, education is the time for students to be able to learn from their mistakes so they do not make a mistake that could potentially get them fired. Education needs to be a time for students to fail without harsh repercussions so they do not make the same mistakes in the real world.

It is clear that using games in education can make a powerful, positive impact. Games as education, when done properly, can help increase a student's retention of information while giving them a new way to learn sometimes difficult subjects at their own pace, and freely being able to make mistakes without it severely punishing their grade. If a game is created poorly however, a student can lose their state of flow and educational value can be lost in the process.

Even if an educator does not want to use games in their classroom, the takeaways from game design should be incorporated into their classroom the best they can. Games allow players to learn how to play at their own pace with the freedom to fail. While it is true that it may not be possible to fully gamify every classroom or implement all the takeaways from game design due to various classroom limitations and deadlines, they still prove that there is a better way to be teaching than using just lectures, homework, and tests. Gamification proves that there is a better way to both teach and learn any given subject.

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Vault of Gebrala: An Educational Game

The Vault of Gebrala: Teacher's Guide page I

The Vault of Gebrala is a game inspired by escape rooms that helps teach Algebra 1 standard AI.RNE.3 as defined by the Indiana State Standards. Players will need to use a mixture of critical thinking, puzzle solving, and algebraic abilities to solve both puzzles in order to find The Vault of Gebrala. Players will also use a companion app which contains a map of Indiana, a radio, and a computer to submit their final answers. These tools will be explained in detail for their respective puzzles.

To start the game, give your students the “Introduction”, “The Root of the Problem”, and “Map Out the Answer” envelopes. The “Introduction” envelope sets the story and tells students what they need to do to win the game. The other two envelopes give the students their respective puzzles and any images associated with the puzzle if needed. When a student as solved both puzzles and put their answers into the computer found in the app, they will see a screen telling them that they have won. At that point, give the students the “Ending” envelope.

Contained in this teacher's guide are step by step instructions on how to solve both puzzles, solutions to each of the math problems, and what topics in algebra are required for each puzzle.

The Vault of Gebrala: Teacher's Guide page II

Puzzle: The Root of the Problem

Lessons Taught: Evaluating integers raised to rational

exponents **Final Solution:** 542019

Puzzle Walkthrough: Students are given a description of a picture and a fraction associated with it. Each image has a number hidden within it which students are supposed to take to the power of the fraction. An example being the picture "(Houses Near Me, ½)" which has the number "1964" hidden as the ZIP Code of the house. When students take 1964 to the half power, they get the answer "44.32". Students are also told that they need the radio found in the companion application. If students tap on the radio, they can type in a radio station. If they type in the answer to one of the problems, the radio will give them one of the digits needed in the final solution. Students order the digits in the same order as the problems are listed for them. Once students have the final code, they have solved the puzzle.

Answer Key:

1. (Houses Near Me, ½) = $1964^{1/2}$ = **44.32**

2. (A Winning Business Plan, ½) = $1249^{1/2}$ = **35.34**

3. (What's the Current Time, ⅓) = $1428^{1/3}$ = **11.26**

4. (Black, White, and Read All Over, ⅓) = $6521^{1/3}$ =

18.68 5. (A Long Way Down, ⅓) = $98593^{1/3}$ = **46.20**

6. (The Stars Above Us, ¼) = $8795^{1/4}$ = **9.68**

The Vault of Gebrala: Teacher's Guide page III

Puzzle: Map Out the Answer

Lessons Taught: Multiplication with exponents, power rule, and evaluating integers raised to rational exponents

Final Solution: Evansville, Indiana

Solution Walkthrough: Students are given 10 problems written in a format in a way such that (3, 2) = 9. Students are given an example of a solved problem and from that they need to infer that they use exponents to solve the problem such that (3, 2) = 3^2 = 9. Some problems will have problems embedded within them, which students can either solve by solving the inner problem first, or by using power rule. Once students have solved every problem, they check the map of Indiana provided in the companion app to see what road is the most common answer. Starting at Indianapolis and following that road will show students what city is their final answer. Once the students know what city the map leads to, they have solved the puzzle.

Answer Key:

1. (8, 2) = 8^2 = **64**
2. (2, 6) = 2^6 = **64**
3. (6.1, 2) = 6.1^2 = **37**
4. (4.1, 3) = 4.1^3 = **69**
5. (2.84, 4) = 2.84^4 = **65**
6. ((2, 3), 2) = $(2^3)^2 = 2^6$ = **64**
7. ((2.84, 2), 2) $(2.84^2)^2 = 2.84^4$ = **65**
8. (8, 2) + (8, 0) = $8^2 + 8^0$ = 64 + 1 = **65**
9. (2,3) * (2,3) = $2^3 * 2^3 = 2^6$ = **64**
10. (5.6, 2) = 5.6^2 = **31**

64 is the most common answer, so students follow road 64 until they see **Evansville** as their final answer.

The Vault of Gebrala: Introduction

Good morning, agents. Today we have finally made progress in our search for the legendary Vault of Gebrala, an ancient vault said to give us the knowledge to every math problem known to mankind. We were able to track down and confront the person who has been keeping it secret from us for all these years, The Vaultkeeper. Unfortunately, they got away, leaving behind only their cell phone in the chase. We need to find both the location of the vault and how to open it based off of only the information we can find off of their cell phone.

This is where you come in. We are giving you all the information we found on their phone. Using the companion app given to you, we believe you can use your mathematical abilities will help us decipher what we've found and help solve the mystery of The Vault of Gebrala.

Rules of the Game: You will be given two puzzles. One puzzle is about finding the Vault of Gebrala, the other is about opening it. Each puzzle has a tool in the companion app that you will need to solve them. Once you have solved both puzzles, use the computer found in the companion app to give your answers. You may start with either puzzle and solve them at any order that you choose.

The Vault of Gebrala: Map out the answer

Before we can even attempt to open the vault, we need to find where The Vaultkeeper hid it. We were tracking where they traveled from his phone, but they put some sort of lock on his phone so we can't figure out exactly what roads they traveled on. **The first road they traveled on was shown as (3, 2) which our agents believe means they traveled on the road 9.** From there, it's up to you to decipher the rest of these. If we can figure out what road they traveled on the most, we can figure out what city the vault is most likely located. Use the map included in the companion app to help solve this case.

1. (8, 2)
2. (2, 6)
3. (6.1, 2)
4. (4.1, 3)
5. (2.84, 4)
6. ((2, 3), 2)
7. ((2.84, 2), 2)
8. (8, 2) + (8, 0)
9. (2,3) * (2,3)
10. (5.6, 2)

Once you know which road The Vaultkeeper traveled on the most, look to see what major city is along that road. Starting with Indianapolis (where we initially found The Vaultkeeper), follow that road to figure out what major city they visit the most. That must be the city where they hid The Vault of Gebrala! Indianapolis is marked as the star on your map.

The Vault of Gebrala: The Root of the problem

Once the vault is found, we will have to deal with the 6-digit combination needed to unlock it. While we have not been able to figure out the combination, we have been searching The Vaultkeeper's search results, and we found a series of random photos and searches. We don't know the meaning behind these searches, but we think they might be related.

- *(Houses Near Me, ½)*
- *(A Winning Business Plan, ½)*
- *(What's the Current Time, ⅓)*
- *(Black, White, and Read All Over, ⅓)*
- *(A Long Way Down, ⅓)*
- *(The Stars Above Us, ¼)*

There must be a connection between these searches and the images below. We also believe something in your companion app might be of help to you. Perhaps then you'll be able to find the **root** of the problem?

The Vault of Gebrala:
Ending

You did it, agents! We have successfully found and opened the Vault of Gebrala. The legends were true. Within it, we found a device capable of solving every single math problem we could ever dream of!

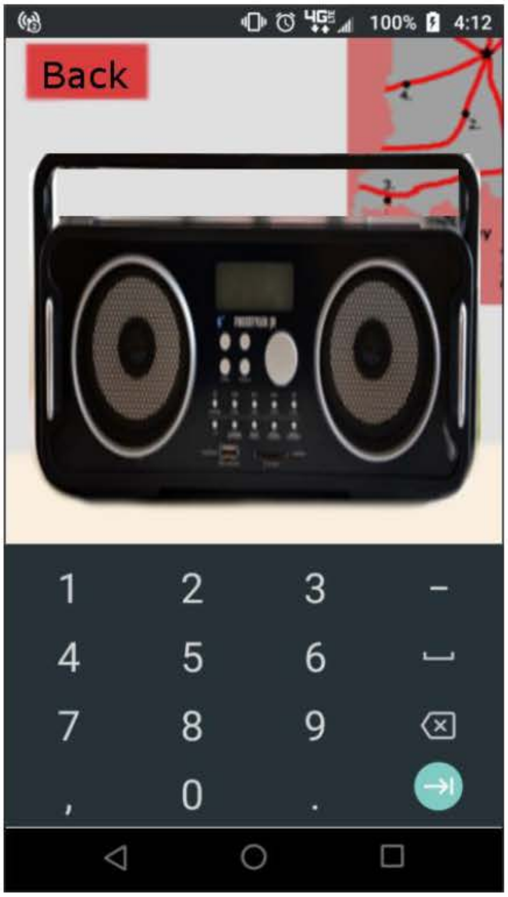
The Treasure of the Vault of Gebrala

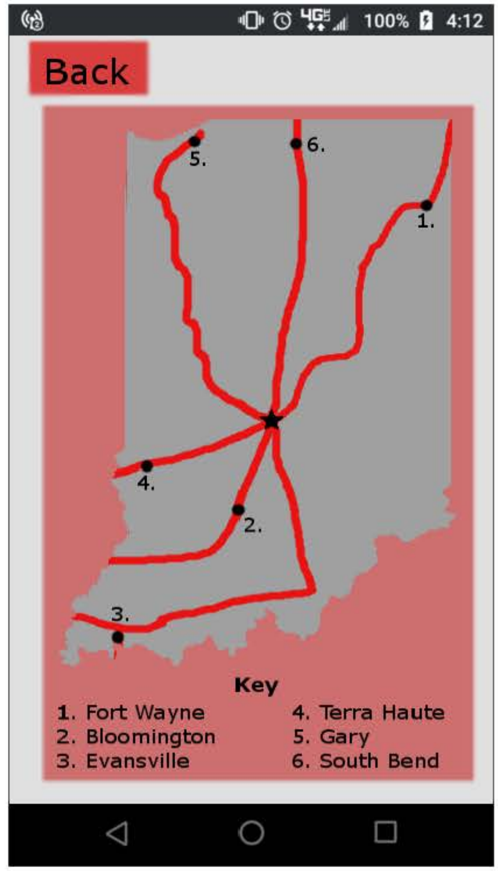
Our agents believe it is called a “kalk-yue-lait-er”. We are still trying to figure out just how it works, but we believe that soon we will never have to do math again thanks to your efforts. I am being told that you will receive the highest of praises from The President soon. Our agents are already searching for a new vault, The Vault of Ulucalcs! We will be in touch if we find any news about its whereabouts.

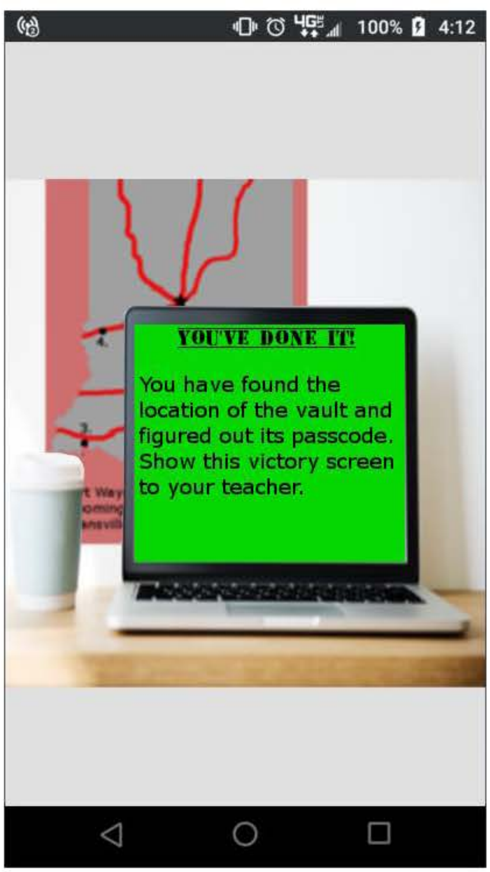
Notecards:

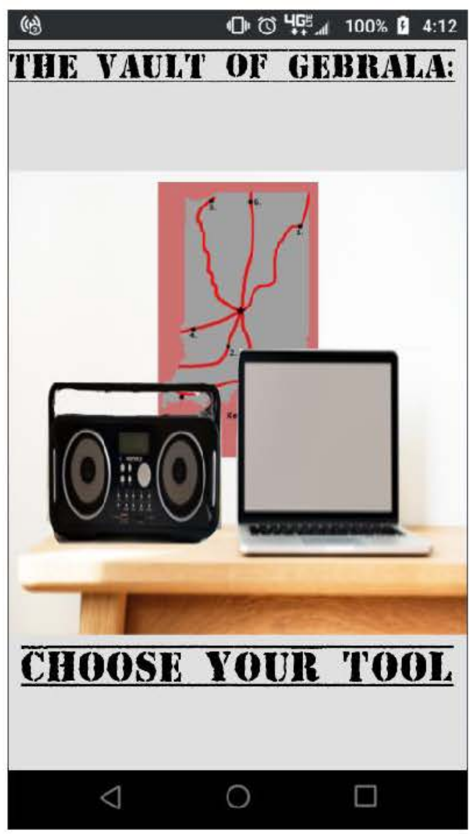

100% 4:12
DO YOU HAVE
THE ANSWERS?
Location:
Passcode:


100% 4:12
WRONG!
One of your answers is wrong. Press the "Back" Button to try again.


Back
1 2 3
4 5 6
7 8 9
0


Back
5.
6.
1.
4.
2.
3.
Key
1. Fort Wayne
2. Bloomington
3. Evansville
4. Terra Haute
5. Gary
6. South Bend

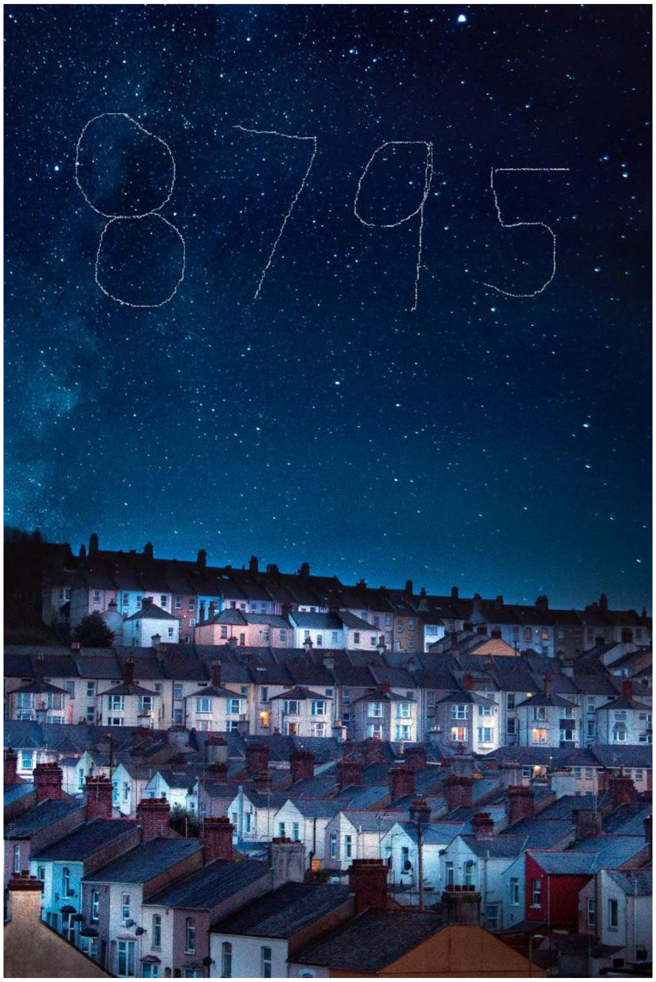

YOU'VE DONE IT!
You have found the location of the vault and figured out its passcode. Show this victory screen to your teacher.


THE VAULT OF GEBRALA:
CHOOSE YOUR TOOL

Images:


1964


98593


8795